

**ontario hydro
research division**

To Mr. F.J. Kee
Director of Research

CEMENTATION OF DECONTAMINATION WASTES

M.A. Habayeb

Solidification of decontamination wastes with high alumina and Portland Type 30 cements (with and without additives) was investigated. Acceptable waste forms were selected on the basis of: formation of workable mixture, minimum volume increase, high waste-to-cement ratio, reasonable composite integrity, minimum waste pretreatment requirements and absence of free water after a curing period of twenty-four hours. High alumina cement is not recommended for solidifying decontamination solutions because of low waste loading. Waste to cement ratios of 0.4:1 can be obtained with Portland 30 cement. Compressive strengths of the waste forms were sensitive to the chemical composition of the waste. Evaluation of cement additives such as vermiculite, sodium silicate, bentonite and epoxy resin showed bentonite to be most suitable increasing waste loading by 25%. Cemented wastes with and without bentonite will be leached to determine the effectiveness of the treatments.

Chemical decontamination of the components of CANDU-PHW nuclear power stations produces large volumes of aqueous radioactive wastes. For example, it is estimated that Darlington GS-A will produce an average volume of 10 m³/yr of radioactive decontamination wastes requiring solidification before storage at BNPDS or disposal/1/. Cement is one possible matrix for the conditioning of aqueous wastes and it has been used at several radioactive waste treatment centres because its physical and chemical properties are well known, process mixing and handling are relatively simple and process costs are low/2-7/.

High alumina and Portland Type 30 cements are common hydraulic cements which harden as a result of chemical reactions between water and cement components followed by crystallization of the hydrated species. Both cement types possess high early strength and are characterized by their tolerance to alkaline solutions /8/. However, there exists a significant difference between the chemical composition of the two cements.

High alumina cement (HAC) is mainly composed of low basicity calcium aluminates (CaO Al₂O₃ and 5 CaO 3 Al₂O₃), whereas Portland cement Type 30 comprises a mixture of calcium silicate

job	file	date	report no.
740632-544-062	837.83	December 8, 1982	82-486-K

(3 CaO Al₂O₃) and tetracalcium alumino ferrite (4 CaO Al₂O₃Fe₂O₃). Detailed chemical compositions of both cement types are given in Table 1/5,9/.

Using these data and equation 1/4/ Lime Saturation Factors (LSF) were calculated as 0.478 for high alumina cement and 1.0 for Portland Type 30 cement.

$$LSF = \frac{CaO - 0.7 (SO_3)}{2.8 (SiO_2) + 1.2 (Al_2O_3) + 0.65 (Fe_2O_3)} \quad [1]$$

It is generally recognized that high LSF values indicate high alkalinity which may allow greater tolerance toward high pH decontamination wastes and also improve the leaching performance of the waste forms by forming insoluble hydroxides of radionuclides.

Therefore, in this work the suitability of both high alumina and Portland Type 30 cements was evaluated for the solidification of aqueous radioactive wastes.

CRITERIA FOR SELECTION OF RECOMMENDED FORMULATIONS

Selection of suitable formulations was based on the following criteria:

1. Formation of a workable mixture.
2. High water resistance.
3. Minimum volume increase.
4. High waste-to-cement loading.
5. Minimum waste pretreatment requirements.
6. Acceptable composite integrity.
7. Absence of moisture or excess water after a curing period of 24 hours.

FORMULATION DEVELOPMENT

Decontamination wastes investigated in this work are reported in Appendix 1. A large number of formulations containing these wastes and high alumina and Portland Type 30 cements (with or without additives) were prepared. A complete list of all experimental formulations is given in Appendices 2 and 3.

SOLIDIFICATION WITH HIGH ALUMINA CEMENT (HAC)

Untreated decontamination wastes solidified with HAC generally produced unacceptable waste forms. For example, untreated alkaline permanganate waste forms exhibited high permanganate leaching under water immersion conditions. Additionally, untreated Calgon, Turco 4521A, sodium tripolyphosphate and potassium persulfate solutions experienced long setting times, phase separation and extensive cracking after solidification. Difficulties encountered in the cementation of the above wastes can be explained on the basis that the reactive chemicals and the organic components contained in the decontamination wastes retarded the crystallization of hydrated calcium aluminate species which are responsible for the development of mechanical strength. For these reasons, treatment of the decontamination wastes prior to cementation

TABLE 1

Chemical Composition of High Alumina (HAC)
and Portland Type 30 Cements (Ref 5 and 9)

Cement	SiO ₂	Al ₂ O ₃	CaO	Fe ₂ O ₃	FeO	TiO ₂	MgO	SO ₃	Na ₂ O	K ₂ O	LSF
High Alumina Cement	8-9	40-41	36-37	5-6	5-6	<2	1.0	0.2	-	-	0.478
Portland Type 30 Cement	20.0	5.2	65.6	2.5	-	0.27	1.4	2.3	0.21	0.44	1.00

is required/10/. The data presented in Appendix 2 indicate that presolidification treatments yielded suitable waste forms with a maximum waste content of 230 g/kg, ie, waste-to-cement ratio of 0.30. An attempt to correlate the mechanical strength with the waste content revealed that the compressive strength of the waste form is sensitive to the chemical composition of the waste. This sensitivity is attributed to the interactions between the waste components and the cement matrix/5/. A typical interaction is retarded setting of high alumina cement by permanganate and citrate ions.

Two drawbacks are associated with the high alumina cementation process. These are high volume increase factors and waste pre-treatment requirements prior to solidification (See Appendix 4). For these reasons, work with HAC was discontinued.

SOLIDIFICATION WITH PORTLAND TYPE 30 CEMENT

Cementation of untreated alkaline permanganate, Turco 4521A and Peroxcit waste yielded unacceptable waste forms. For example, untreated alkaline permanganate waste forms possessed reasonable mechanical strength, but exhibited high permanganate leaching rates when exposed to water. Citrate and oxalate ions present in both Turco 4521A and Peroxcit wastes retarded the setting of Portland Type 30 cement which resulted in waste forms with poor composite integrity. To improve the physical characteristics and leaching performance of these waste forms, presolidification treatments prior to cementation are required/10/. A summary of treated and untreated decontamination wastes solidified with Portland Type 30 cement is given in Appendix 3. The data in this Appendix support the following observations:

1. The maximum waste-to-cement ratio increased from an average value of 0.30 to 0.40 when Portland Type 30 cement was substituted for high alumina cement.
2. As noted for HAC waste forms, the compressive strengths of wastes solidified with Portland Type 30 cement were sensitive to the chemical composition of the decontamination wastes. For example, the compressive strengths of pH-adjusted Peroxcit and Turco 4512 wastes were 12.6 MPa and 34.8 MPa, respectively (at a waste-to-Portland Type 30 cement ratio of 0.40).
3. In general, treated decontamination waste forms exhibited lower compressive strength values than untreated waste forms. This is due to an increase in the salt content in the treated waste forms.
4. The maximum waste content for solidified potassium persulfate wastes is 375 g/kg which corresponds to a waste-to-Portland Type 30 cement ratio of 0.60. A probable cause for this high ratio is the hydrophilic nature of the persulfate ions ($S_2O_8^{2-}$).

The preceding discussion suggests that Portland Type 30 cement is preferred for cementation of treated and untreated decontamination wastes. The recommended waste/Portland Type 30 cement (without additives) formulations are presented in Appendix 6.

PORTLAND TYPE 30 CEMENT - ADDITIVES FORMULATIONS

Portland Type 30 cement is a porous material, ie, develops an open cell structure after curing. This can lead to high radionuclide release by leaching and/or exchange/5/. Vermiculite, sodium silicate, bentonite and epoxy resin have been suggested as additives for Portland Type 30 cement to improve radionuclide retention, minimize the water permeability of the solidified waste and increase the waste loading of the cement matrix/4,5/. A summary of all cement/additive formulations is given in Appendix 5.

Vermiculite was expected to allow an increase in the waste content of the cemented decontamination solutions. In this work, the addition of vermiculite to Portland Type 30 cement increased the waste-to-cement ratio from 0.40 to 0.7, but the resultant waste forms were characterized by poor composite integrity.

Sodium silicate was investigated for improvement of setting properties and loading efficiency of the cement matrix/11/. The data presented in Appendix 5 show that increasing the silicate content to 250 g/kg dry cement produced waste forms with unacceptable mechanical strength. Furthermore, the addition of silicate did not improve the loading efficiency of the cementation process.

Bentonite has been mixed with Portland Type 30 cement formulations to reduce radiocesium leaching rates significantly/4/. Experience has shown that these rates are dependant on the waste type and the waste-cement formulation/12/. The results of this work show that not only did bentonite increase the loading efficiency of the cement matrix by about 25%, but it also produced waste forms with good mechanical properties (see Appendix 5, .

Epoxy resin was added to cement formulations to minimize the water permeability of the waste forms. The data in Appendix 5 show that dispersing the waste/cement formulation in epoxy resin at 250 g epoxy/kg cement produced waste forms with excellent water resistance characteristics. The principal disadvantages of epoxy resin addition are high cost and no increase in the waste loading efficiency of the cement matrix.

A comparison of advantages and limitations of each cement/additive formulation, reveals that the most suitable additive is bentonite. Suitable formulations should be based on the cement/waste formulations given in Appendix 6 plus 100 g bentonite/kg cement.

CONCLUSIONS

1. Presolidification treatments of most decontamination wastes were required prior to cementation.
2. Acceptable formulations for the solidification of treated and untreated decontamination wastes with Portland Type 30 cement (with and without additives) have been developed. The optimum waste-to-cement ratio for all decontamination wastes is 0.40.

3. Work with high alumina cement was discontinued because of low waste loading efficiency and most untreated decontamination wastes exhibited poor composite integrity after solidification.
4. Compressive strength values associated with all recommended formulations were found to be sensitive to the chemical composition of the waste.
5. Addition of bentonite at a ratio of 100 g/kg Portland Type 30 cement increased the waste loading efficiency of the cement matrix by about 25% without adversely affecting the composite integrity of the waste forms.

Approved:

Submitted:

D. Harrison

D. Harrison
Manager
Chemical Research Dept. *ph*

MAH:aba

M. A. Habayeb

M.A. Habayeb *MAH*
Chemist
Organic Section

REFERENCES

1. Carter, T.J., "Radioactive Waste Management Practices At A Large Canadian Electrical Utility". Radioactive Waste Management, Vol 2(4), 381 (1982).
2. Mergan, L. and M. Vandorpe, "Low Level Waste Management. A Brief Overview of the Western European Countries". Presented at the American Nuclear Society Topical Meeting on the Treatment and Handling of Radioactive Wastes. Richland, Washington, April 19-22 (1982).
3. Treatment of Low - and Intermediate - Level Radioactive Waste Concentrates. IAEA, TRS, No 82, Vienna (1968).
4. Burns, R.H., "Solidification of Low - and Intermediate - Level Wastes", Atomic Energy Rev 9(3), (1971).
5. Alternatives for Managing Wastes from Reactors and Post Fission Operations in the LWR Fuel Cycle, Vol 2: "Alternatives for Waste Treatment". Report No ERDA-76-43, US Energy Research and Development Administration, Washington, DC (May 1976).
6. Pojasek, Robert B. (ed), "Toxic and Hazardous Waste Disposal", Vol I. Processes for Stabilization/Solidification. Ann Arbor Science Publishers Inc., Michigan. 1979. pp 44-51.
7. Golinski, Marek; Ferenc, Marian; Tomczak, Woldzimierz and Cholerzynski, Andrezej, "The Influence of Radioactive Waste Solidification Methods and Storage Conditions on the Migration and Dispersion of Radionuclides in the Terrestrial Environment", Institute of Nuclear Research, Warszawa, 1979. IAEA No 2173/RB.
8. Neville, Adam, "HAC Concrete", A Halsted Press Book, John Wiles and Sons. New York, NY 1975. pp 9-20.
9. Blanks, R.F. and H.L. Kennedy, "The Technology of Cement and Concrete", Vol I, Concrete Materials, John Wiley and Sons, Inc, New York, NY 1955. pp 28 and 204.
10. Habayeb, M.A., "Presolidification Treatments of Decontamination Wastes", Research Report No 81-468-K.
11. Heacock, H.W., "Alternative Nuclear Waste Solidification Processes", Waste Management 75, University of Arizona, p 177. July, 1975.
12. Savannah River Laboratory Quarterly Report - Waste Management, January - March 1973, DPST-73-125-1, Savannah River Laboratory, Aiken, SC, 1973.

APPENDIX 1

CHEMICAL COMPOSITION OF DECONTAMINATION WASTES

Code Name or Abbreviation	Chemical Composition	g/L	pH	Density g/mL
1. Alkaline permanganate (AP)	KMnO_4 NaOH	30 100	13.0	1.09
2. Turco 4512	H_3PO_4	50	1.4	1.08
3. Calgon	$\text{Na}_6\text{P}_6\text{O}_{18}$	10.0	10.0	
4. Pickering Solution	$\text{Na}_6\text{P}_6\text{O}_{18}$ $\text{NaC}_{15}\text{H}_{23}\text{SO}_3$ $\text{Na}_2\text{C}_{10}\text{N}_2\text{H}_{14}\text{O}_8$	5.0 2.5 2.5	6.5	1.01
5. Sodium tripolyphosphate	$\text{Na}_5\text{P}_3\text{O}_{10}$	10	9.0	
6. Peroxide bicarbonate	$\text{Na}_2\text{CO}_3 \cdot 10 \text{H}_2\text{O}$ NaHCO ₃ H ₂ O ₂	72 34 20	9.8	1.05
7. Turco 4521A	$(\text{NH}_4)_2\text{HC}_6\text{H}_5\text{O}_7$ H ₂ C ₂ O ₄	33 17	4.0	1.03
8. Peroxcit	H ₂ C ₂ O ₄ C ₆ H ₈ O ₇ H ₂ O ₂	51 31 12	1.4	1.02
9. Potassium persulfate	$\text{K}_2\text{S}_2\text{O}_8$ KOH	54 56	13.8	1.10

APPENDIX 2

WASTE LOADING AND COMPRESSIVE STRENGTH VALUES OF DECONTAMINATION WASTES SOLIDIFIED WITH HIGH ALUMINA CEMENT

Waste	Treatment	Waste-to- Cement Ratio	Compressive Strength MPa	Comments	
				Waste Form Characteristics	Water Imme- diate Test*
1. Alkaline permanganate	1. Untreated (pH=13.5)	0.30	-	-	Failed
	2. pH=8 (adjusted with Turco 4512)	0.30	-	Acceptable waste Form (AWF)	Passed
	3. pH=8 + Turco 4521A	0.30	-	Setting occurred after 3 days	Passed
	4. Treated with IRN-150	0.50	-	Setting occurred after 3 days	Failed
2. Turco 4512	5. Untreated (pH=1.4)	0.30	38.1	AWF AWF AWF	Passed Passed Passed
	6. pH=8.0	0.30	44.1		
	7. Aluminum chloride, 30 g per L of waste	0.30	17.2		
3. Calgon	8. Untreated (pH=10)	0.1, 0.2, 0.3 0.30	-	Phase separation AWF	Failed Passed
	9. Barium chloride, 30 g per L of waste		7.9		
4. Pickering Solution	10. Untreated (pH=6.5)	0.20	20.3	AWF	
5. Sodium tripolyphos- phate (STPP)	11. Untreated (pH=9.0)	0.20, 0.25, 0.30	-	Phase separation	Failed
6. Peroxide bicarbonate	12. Untreated (pH=9.8)	0.20 0.20	-	Phase separation Phase separation	Failed Failed
	13. Barium chloride, 12 g per L of waste		-		

APPENDIX 2 (Cont'd)

WASTE LOADING AND COMPRESSIVE STRENGTH VALUES OF
DECONTAMINATION WASTES SOLIDIFIED WITH HIGH ALUMINA CEMENT

Waste	Treatment	Waste-to-Cement Ratio	Compressive Strength MPa	Waste Form Characteristics	Comments	Water Immersion Test
7. Turco 4521A	14. Untreated (pH=4.0)	0.30	-	No setting due to citrate ions	-	-
	15. pH=8.0	0.30	-	No setting due to citrate ions	-	-
	16. Alkaline permanganate	0.30	-	Setting occurred within 3 days	-	-
8. Peroxocit	17. Untreated (pH=1.4)	0.30	-	Poor mechanical strength	Failed	-
	18. Barium hydroxide	0.40	-	Surface cracking	-	-
9. Potassium persulfate	19. Untreated (pH=13.8)	0.60	-	Surface cracking	-	-
	20. pH=8.0	0.60	-	Surface cracking	-	-
	21. Turco 4521A	0.60	-	Poor mechanical strength	-	-

* Water Immersion Test: To pass a sample must maintain integrity over a two-week immersion in distilled water.

APPENDIX 3

WASTE LOADING AND COMPRESSIVE STRENGTH VALUES OF DECONTAMINATION WASTES SOLIDIFIED WITH PORTLAND TYPE 30 CEMENT

Waste	Treatment	Waste-to-Cement Ratio	Compressive Strength MPa	Comments	
				Waste Form Characteristics	Water Immersion Test
1. Alkaline permanganate	1. Untreated (pH=13.5)	0.40	-	Unacceptable	Failed
	2. pH adjusted with Turco 4512 (pH=8.0)	0.40	-	Unacceptable	Failed
	3. pH adjusted with H ₂ SO ₄ and then mixed with Turco 4521A	0.40	20.6	Acceptable Waste Form (AWF)	Passed
2. Turco 4512	1. Untreated (pH=3.95)	0.40	33.4	Setting time 24 hours	Passed
	2. pH adjustment with NaOH (pH=8.0)	0.40	34.8	Setting time 24 hours	Passed
	3. Treatment with aluminum chloride, 30 g per L of waste.	0.60	23.3	AWF	Passed
3. Calgon	1. Untreated	0.35	53.3	AWF	-
4. Pickering Solution	1. Untreated	0.40	39.2	AWF	-
5. Sodium tripolyphosphate (STPP)	1. Untreated	0.35	47.4	AWF	Passed
		0.40	-	AWF	-

APPENDIX 3 (Cont'd)

WASTE LOADING AND COMPRESSIVE STRENGTH VALUES OF
DECONTAMINATION WASTES SOLIDIFIED WITH PORTLAND TYPE 30 CEMENT

Waste	Treatment	Waste-to-Cement Ratio	Compressive Strength MPa	Comments	
				Waste Form Characteristics	Water Immersion Test
6. Peroxide bicarbonate	1. Untreated	0.40	33.3	AWF	Passed
	2. Treated with barium chloride - 12 g/L of waste	0.50	-	Cracks after 3 days	Failed
		0.40	52.2	AWF	-
7. Turco 4521A	1. Untreated	0.35	-	Soft; poor mechanical integrity	Failed
	2. pH adjusted to 8.0 with sodium hydroxide	0.35	39.5	AWF	-
	3. Treated with barium chloride, 30 g per L of waste	0.40	14.1	AWF	-
8. Peroxycit	1. Untreated	0.35	-	No setting	Failed
	2. pH adjusted to 8.0	0.35	12.6	AWF	-
	3. pH adjusted with barium hydroxide	0.60	-	Swelling	Failed
	4. Treatment with aluminum chloride 23 g per L of waste, then pH adjusted to 8-0	0.40	14.1	AWF	-
9. Potassium persulfate	1. Untreated (pH=13.8)	0.40	-	Setting time 2 hours	-
		0.50	-	"	-
		0.60	13.8	AWF	Passed
		0.70	8.70	Poor mechanical integrity	Failed
	2. pH adjustment with H ₂ SO ₄ (pH=8.0)	0.50	-	AWF	-
	3. pH adjustment + Turco 4521A (pH=4.0)	0.50	-	Poor mechanical integrity	Failed
	4. Treatment with Turco 4521A, then adjust pH to 8.0	0.35	-	AWF	-

APPENDIX 4

VOLUME INCREASE FACTORS* OF CEMENTED DECONTAMINATED WASTES

No	Waste	Vol of Waste mL	Dimensions of Waste Form			Volume Increase Factors of Waste			Forms Containing Portland Type 30 Cement
			r, cm	Height, cm	Vol, cc	HAC	Portland cement and Bentonite		
1	Alkaline Permanganate pH adjusted and Turco 4521A	30	2.51	3.2	63.3	2.11	1.96		1.67
2	Turco 4512 treated with 30g of AlCl ₃ per L of solution	30	2.51	3.2	63.3	2.11	1.51		1.47
3	Calgon-untreated	30	2.51	3.2	63.3	2.11	1.84		1.91
4	Pickering Soln - untreated	20	2.51	3.0	59.3	2.92	1.87		1.82
5	STPP - untreated	30	2.51	3.2	63.3	2.11	1.71		1.91
6	Peroxide Bicarb - treated with aluminum chloride	20	2.51	2.6	51.4	2.57	1.77		1.82
7	Turco 4521A - untreated	30	2.51	3.2	63.3	2.11	1.76		1.72
8	Peroxycit Untreated	30	2.51	3.5	69.2	2.31	1.91		1.82
9	Potassium Persulfate	60	2.51	4.4	81.03	1.45	1.70		1.35

*Vol Increase Factor = Vol of Waste Form/Vol of Decontamination Waste

APPENDIX 5

FORMULATIONS FOR SOLIDIFYING DECONTAMINATION WASTES WITH PORTLAND TYPE 30 CEMENT AND VARIOUS ADDITIVES

Waste	Percentage of Additive based on wt of dry cement	Waste-to- Cement Ratio including additive	Compressive Strength MPa	Waste Form Characteristics	Comments Water Immersion Test*
1. Alkaline permanganate treated with Turco 4521A	5% vermiculite 5% silicate 25% silicate 10% bentonite 25% epoxy resin	0.50 0.40 0.40 0.50 0.40	Nil 29.7 8.8 25.3 20.7	Unacceptable AWF Poor mech. strength AWF AWF	- Hi pH leachate Hi pH leachate Passed Passed
2. Potassium persulfate: untreated 2.1 Potassium persul- fate at pH=8.0	5% vermiculite 5% silicate 25% silicate 5% silicate 25% silicate 10% bentonite	0.60 0.60 0.60 0.70 0.70 0.75	Nil 8.7 6.5 5.6 2.5 10.5	Unacceptable AWF Poor mech strength AWF AWF AWF	Failed Passed Hi pH leachate - - Passed
3. Peroxide bicarbonate: untreated 3.1 Peroxide bicarbo- nate treated with barium chloride	5% vermiculite 5% silicate 5% silicate 25% silicate 10% bentonite 25% epoxy resin	0.40 0.40 0.40 0.40 0.50 0.40	- 21.2 25.7 6.9 15.3 18.8	Unacceptable AWF AWF Poor mech. strength AWF AWF	- - - - Passed Passed
4. Turco 4521A: 4.1 pH adjusted (pH=8.0) 4.2 Treated with barium chloride	5% silicate 5% silicate 25% silicate 10% bentonite 25% epoxy resin	0.35 0.40 0.40 0.50 0.40	33.9 19.8 6.4 - 22.9	AWF AWF AWF AWF AWF	Hi pH leachate Hi pH leachate Hi pH leachate Passed Passed

APPENDIX 5 (Cont'd)

FORMULATIONS FOR SOLIDIFYING DECONTAMINATION WASTES WITH
PORTLAND TYPE 30 CEMENT AND VARIOUS ADDITIVES

Waste	Percentage of Additive based on wt of dry cement	Waste-to- Cement Ratio including additive	Compressive Strength MPa	Comments	
				Waste Form Characteristics	Water Immersion Test
5. Peroxit: 5.1 Adjusted to pH 8.0 5.2 Treated with AlCl ₃	5% vermiculite	0.40	-	Unacceptable	Failed
	5% silicate	0.35	10.9	AWF	-
	5% silicate	0.40	17.9	AWF	-
	25% silicate	0.40	-	Poor mech. integrity	-
	10% bentonite	0.50	10.4	AWF	Passed
	25% epoxy resin	0.40	-	AWF	Passed
6. Turco 4512: 6.1 Untreated 6.2 pH=8.0 6.3 Treated with AlCl ₃	5% silicate	0.40	33.1	AWF	Hi pH leachate
	5% silicate	0.40	32.3	AWF	-
	5% silicate	0.60	17.9	AWF	-
	25% silicate	0.60	7.0	-	-
	10% bentonite	0.65	11.4	AWF	Passed
	25% epoxy resin	0.60	25.7	AWF	Passed
7. Pickering solution: 7.1 Untreated	5% vermiculite	0.50	Nil	Unacceptable	-
	5% silicate	0.40	29.7	AWF	-
	25% silicate	0.40	10.3	Poor composite integrity	-
	10% bentonite	0.50	14.8	AWF	Passed
8. Calgon: 8.1 Untreated	5% silicate	0.35	16.4	AWF	Hi pH leachate
	25% silicate	0.35	7.3	Poor mechanical strength	-
	10% bentonite	0.45	20.7	AWF	Passed

APPENDIX 5 (Cont'd)

FORMULATIONS FOR SOLIDIFYING DECONTAMINATION WASTES WITH
PORTLAND TYPE 30 CEMENT AND VARIOUS ADDITIVES

Waste	Percentage of Additive based on wt of dry cement	Waste-to- Cement Ratio including additive	Compressive Strength MPa	Comments	
				Waste Form Characteristics	Water Immersion Test
9. Sodium tripolyphos- phate (STPP): 9.1 Untreated	5% silicate	0.35	36.3	AWF	-
	25% silicate	0.35	-	Poor	-
	10% bentonite	0.45	-	AWF	Passed

* Water Immersion Test: To pass a sample must maintain composite integrity over two weeks of immersion in distilled water.

APPENDIX 6

RECOMMENDED FORMULATIONS FOR THE SOLIDIFICATION OF TREATED AND UNTREATED DECONTAMINATION WASTES WITH PORTLAND TYPE 30 CEMENT

1. Alkaline Permanganate Waste: Adjust the pH to 9.0 with Turco 4512. Mix equal volumes of this solution with Turco 4521A. Allow to stand overnight. Mix with Portland Type 30 cement in a waste-to-cement ratio of 0.40. Allow to cure for a minimum of 7 days.
2. Turco 4512: Dissolve 30.0 g of aluminum chloride ($AlCl_3$) in each 1.0 liter of Turco 4512. Mix with Portland Type 30 cement in a ratio of waste-to-cement of 0.60. Allow to cure for a minimum of 7 days.
3. Peroxide Bicarbonate Solution: Dissolve 15.0 g of barium chloride in each 1.0 liter of waste. Mix waste with Portland Type 30 cement in a waste-to-cement ratio of 0.40.
4. Peroxcit Solution: Dissolve 23.0 g of aluminum chloride in each liter of waste. Adjust pH to 8.0 with 10 N sodium hydroxide (use about 12 mL of the hydroxide solution for each 100 mL of waste). Mix this waste with cement in a waste-to-cement ratio of 0.40.
5. Turco 4521A Waste: Dissolve 30.0 g of barium chloride in each liter of waste. Adjust pH to 8.0 with 10 N sodium hydroxide. Mix with Portland Type 30 cement in a waste-to-cement ratio of 0.40.
6. Pickering Solution: Mix untreated Pickering solution with Portland Type 30 cement in a waste-to-cement ratio of 0.40.
7. Calgon: Mix untreated Calgon with Portland Type 30 cement in a waste-to-cement ratio of 0.35.
8. Sodium Tripolyphosphate (STPP): Mix untreated STPP with Portland Type 30 cement in a waste-to-cement ratio of 0.35.
9. Potassium Persulfate: Adjust pH to 8.0 with 6.0 M sulfuric acid (32.5 mL of acid per L of waste) of Turco 4512. Mix with Portland Type 30 cement in a waste-to-cement ratio of 0.7.

POOR

QUALITY

ORIGINAL